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POWER DISTRIBUTION ADAPTABLE TO DIFFERENT POWER SUPPLIES

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POWER DISTRIBUTION ADAPTABLE TO DIFFERENT POWER SUPPLIES

BACKGROUND OF THE INVENTION

5 ### 1. Field of the Invention

[0001]   The present invention relates generally to rack mount computer systems. More specifically, power distribution systems and methods for adaptation of the power distribution to computer systems to varying electrical loads and/or varying power supply inputs are disclosed.

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2. Description of Related Art

[0002]   Many of today's more complex computing systems such as computer server systems are often rack-mounted systems in which a number of removable electronics modules, such as electronics trays, are positioned and stacked relative to each other in a

15 shelf-like manner within a frame or rack. Rack-mounted systems allow the arrangement of several of the electronics modules in a vertical orientation for efficient use of space. Each electronics module can be slid into and out of the rack-mounting system. Typically, the electronics modules are inserted from the front of the rack and various cables such as data cables, power cables, etc., are connected to the electronics modules at the front

20 and/or rear of the rack.

[0003]   Each electronics module may correspond to a different server or each electronics module may hold one or more components of a server. Examples of electronics modules include modules for processing, storage such as random access

memory (RAM), network interfaces and controllers, disk drives such as floppy disk drives, hard drives, compact disk (CD) drives, and digital video disk (DVD) drives, parallel and serial ports, small computer systems interface (SCSI) bus controllers, video controllers, power supplies, and so forth. A server farm in today's computing environment may include numerous racks that hold various types of computer-related modules.

[0004]   Rack mount computer systems are often shipped to and used in locations such as central offices in different countries with varying electrical systems serving as the power inputs to the rack systems. Typically, each server uses a universal input power supply module which is a power supply that allows the server to operate properly with input voltages from 90V - 240VAC (volts alternating current). For example, in North America, the electrical systems typically provide 115V/15A (volts/amperes), 115V/20A and/or 208V/20A circuits while 230V/16A and/or 230V/32A circuits are common in Europe.

[0005]   With different voltages and amperages at various locations, the rack mount computer systems need to be wired accordingly in order to distribute power efficiently and to maintain load balancing to prevent circuit overload. Currently, the rack mount computer systems may be shipped ready to be adapted and configured by a service technician to the electrical system available at the destination location. However, such a process is time consuming, labor intensive and costly, particularly as a large rack typically have dozens of electrical plugs that need to be wired to a corresponding electrical outlet or source. With multiple racks, such a process may take several days for a service technician to configure just the wiring for the numerous racks being installed at the destination location.

[0006] In addition, at many collocations, service providers often have to pay for each circuit used. Thus, it would be desirable to design the computer systems such that the systems draw the maximum amount of power from each outlet or circuit being used. However, over time, the computer systems are likely to be updated and/or upgraded, for example, with faster central processing unites (CPUs), more memory, larger disk drives, etc. Such upgrades typically increase the amount of power drawn by the system. To account for the increased power requirements of possible future upgrades, the engineering designing the rack system may estimate the amount of power requirement increases and include and account for this estimate in the power circuit configurations. However, if the estimate turns out to be too low, there is a large cost associated with rewiring the racks for the necessary extra service cords. Even if the estimate turned out to be sufficient, a given rack may spend most of its life operating at well below its maximum power rating. Such under-utilization of the available power is not cost effective given that the service provider pays for each circuit used.

[0007] Furthermore, even if no upgrades are performed, during an initial installation testing, the systems are typically operated at substantially more current than that drawn during normal use. While the testing is performed only for a short period of time (e.g., a few days) relative to the useful life of the system (e.g., three years), the system nonetheless needs to be provisioned with sufficient current to meet this unusually high demand during the testing. The test may be performed by wiring the system to additional power cords and then rewiring the system to use fewer power cords at the lower currents of normal operation, a time consuming task. The alternative may be to unplug half of the servers and test each half of the rack sequentially, thereby doubling the test time.

[0008]   Thus, it would be desirable to provide a system and method to conveniently adapt the distribution of power for a computer system to varying electrical loads and/or with varying power inputs.

SUMMARY OF THE INVENTION

5   [0009]   Power distribution systems and methods for adaptation of the power distribution to computer systems to varying electrical loads and/or varying power supply inputs are disclosed. It should be appreciated that the present invention can be implemented in numerous ways, including as a process, an apparatus, a system, a device, or a method. Several inventive embodiments of the present invention are described

10   below.

[0010]   The power distribution system may generally include power connectors and power distribution terminals, each terminal is connected to a group of the power connectors configured to carry electrical power to electronics components of the computing system. The terminals may be selectively divisible into sets of grouping

15   combinations, each grouping combination within each set corresponding to approximately the same number of power connectors. The terminals may be configured to be connected to power supply circuits in accordance with the selected set of grouping combinations. For example, each group of power connectors may include at least approximately 1/12 and at most approximately 1/4 of the total number of power

20   connectors. Each of power connectors may be approximately 1/12, 1/6 or 1/4 of the number of power connectors. Each set of grouping combinations may include 2, 3 or 4 grouping combinations. As an example, the power distribution terminals may include 6

terminals, 2 connected to approximately 1/4 of the power connectors, 2 connected to

approximately 1/6 of the power connectors, and 2 connected to approximately 1/12 of the

power connectors. As another example, the power distribution terminals may include 8

terminals, 4 connected to approximately 1/6 of the power connectors and 4 connected to

5   approximately 1/12 of the power connectors.

[0011]   The method for distributing power among multiple electronics components or

modules of a computing system may generally include selecting a set of power connector

grouping combinations and connecting each power distribution terminal to a power

supply circuit in accordance with the selected set of grouping combinations. Each

10   grouping combination within each set of grouping combinations corresponds to

approximately the same number of power connectors. The number of power supply

circuits is equal to the number of grouping combinations in the selected set of grouping

combinations and each terminal is connected to a corresponding group of power

connectors.

15   [0012]   These and other features and advantages of the present invention will be

presented in more detail in the following detailed description and the accompanying

figures which illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

20   [0013]   The present invention will be readily understood by the following detailed

description in conjunction with the accompanying drawings, wherein like reference

numerals designate like structural elements.

[0014]   FIGS. 1 is a schematic diagram of a rack mount computer system with an illustrative power distribution terminal block to facilitate configuration of the rack mount computer system with varying electrical loads and/or varying power inputs.

[0015]   FIG. 2 is a schematic diagram illustrating the power distribution terminal block of FIG. 1 in more detail.

[0016]   FIG. 3 is a block diagram illustrating one example of a configuration of a power distribution terminal block to facilitate configuration of a rack mount computer system with varying electrical loads and/or varying power inputs.

[0017]   FIG. 4 is a block diagram illustrating another example of a configuration of a power distribution terminal block to facilitate adaptation of a rack mount computer system with varying electrical loads and/or varying power inputs.

[0018]   FIGS. 5-1 and 5-2 are tables illustrating examples of groupings and examples of combinations of groupings for a power distribution terminal block configured similarly to that shown in FIG. 3 with different number of power connectors adapted to operate with different number of circuits.

[0019]   FIGS. 6-1 and 6-2 are tables illustrating examples of groupings and examples of combinations of groupings for a power distribution terminal block configured similarly to that shown in FIG. 4 with different number of power connectors adapted to operate with different number of circuits.

[0020]   FIG. 7 is a flowchart illustrating a process for configuring the power connectors relative to the terminals of a power distribution terminal block of a computer system.

[0021]   FIG. 8 is a flowchart illustrating a process for configuring a power distribution terminal block of a computer system varying electrical loads and/or varying power inputs.

DESCRIPTION OF SPECIFIC EMBODIMENTS

5   [0022]   Power distribution systems and methods for adaptation of the power distribution to computer systems to varying electrical loads and/or varying power supply inputs are disclosed. The following description is presented to enable any person skilled in the art to make and use the invention. Descriptions of specific embodiments and applications are provided only as examples and various modifications will be readily

10   apparent to those skilled in the art. The general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention. Thus, the present invention is to be accorded the widest scope encompassing numerous alternatives, modifications and equivalents consistent with the principles and features disclosed herein. For purpose of clarity, details relating to technical material that

15   is known in the technical fields related to the invention have not been described in detail so as not to unnecessarily obscure the present invention.

[0023]   FIGS. 1 is a schematic diagram of a rack mount computer system 10 with an illustrative power distribution terminal block 20 to facilitate configuration of the rack mount computer system with varying electrical loads and/or varying power inputs. FIG.

20   2 is a schematic diagram illustrating the power distribution terminal block 20 of FIG. 1 in more detail. As shown, the rack mount computer system 10 includes various power connectors 30 at both the front and back of the rack system 10. Typically, the same

number of power connectors 30 may be provided at the front and back of the rack system 10, corresponding to the left and right sides of the power distribution terminal block 20. However, any other suitable configuration of power connectors and/or the power distribution terminal block 20 may be employed.

5   [0024]   FIG. 3 is a block diagram illustrating one example of a configuration of a power distribution terminal block 20 to facilitate configuration of a rack mount computer system with varying electrical loads and/or varying power inputs. The power distribution terminal block 20 includes several terminals 22 connected to various power connectors or sockets 30 of the rack system. Typically, the rack system includes various electronics

10   modules each having one or more power connectors 30 through which the corresponding electronics module draws power. The power connectors 30 are divided into groups that terminate at a terminal 22. Each power connector 30 is connected to one terminal 22 and multiple power connectors 30 may be connected to a single terminal 22. Each group of power connectors includes a portion of the power connectors 30.

15   [0025]   The power distribution terminal block 20 allows the rack mount computer system to be easily and quickly configured to varying electrical loads and/or varying power inputs. For example, with respect to varying power inputs, at central office locations or other collocations in North America, the electrical systems typically provide 115V/15A, 115V/20A and/or 208V/20A power supply circuits while 230V/16A and/or

20   230V/32A power supply circuits are common at locations in Europe. However, it is to be understood that the power distribution terminal block 20 may be configured such that the rack mount system may be adapted for any other suitable voltage/ampacity power supply circuits.

[0026]   In addition, the power distribution terminal block 20 and its configuration also allow the rack mount computer system to be easily and quickly configured to varying electrical loads. In particular, a given computer system is likely to be updated and/or upgraded over time, for example, with faster CPUs, more memory, larger disk drives, and so forth. Such upgrades typically increase the amount of power drawn by the system.

[0027]   To account for the increased power requirements of potential future upgrades, the system may be designed with sufficient headspace to account for an estimated increase in the electrical load from such system upgrades. However, designing the system with sufficient headspace for power usage is not cost effective as, at many collocations, service providers pay for each circuit used. In other words, designing the system with sufficient headspace thus requires the use of unnecessary additional circuits before these additional circuits are actually needed. In addition, the estimated headspace may turn out to be insufficient thus requiring the system to be rewired.

[0028]   Alternatively, the system may be designed without headspace and is rewired with each upgrade such that the service provider uses and pays only for circuits that are currently needed. Conventionally, such rewiring is time consuming and inconvenient and thus is also associated with additional costs. However, with the power distribution terminal block 20 and its configuration, the system can be configured to maximize the power drawn from each power supply circuit while still allowing the configuration of the power distribution to be quickly and easily changed with each upgrade and/or other change in the electrical load and/or in the input power supply. As is evident, maximizing the amount of power drawn from each power supply outlet or circuit minimizes the number of power supply circuits used and thus decreases costs.

[0029]   As is evident, the power distribution terminal block 20 enables the computer systems, such as rack mount computer system, to be quickly and easily reconfigured whenever the electrical loads of the system are modified (e.g., initial system testing and/or system upgrades), and/or whenever the power inputs are modified (e.g., power supply circuit with different voltage and/or amperage). For example, as noted above, the system may be wired for additional power supply circuits for purposes of initial installation testing in which the system is operated at a substantially higher current level than during normal use. With the power distribution terminal block 20, the system may be quickly and easily rewired for fewer power supply circuits after the initial installation testing is complete.

[0030]   In the example shown in **FIG. 3**, the power connectors 30 are provided at both the front and back of the rack system for purposes of convenience. In addition, the same number of power connectors 30 may be provided at the front and back of the rack system, corresponding to the left and right sides of the power distribution terminal block 20. For example, 21 power connectors may be provided at the front and at the back of the rack system for a total of 42 power connectors. However, any other suitable configuration of power connectors and/or the power distribution terminal block 20 may be employed.

[0031]   The power connectors 30 are divided into groups such that each group includes a portion of the power connectors 30 terminating at a corresponding terminal 22. It is noted that, for purposes of clarity, the portion used herein refers to a portion of the total number of power connectors for the computer system. For example, groups I and II may each include approximately 1/6 while groups II and IV may each include approximately 1/12 of the total number of the power connectors 30. Similarly, groups V and VI may each include approximately 1/6 while groups VII and VIII may each include

approximately 1/12 of the total number of power connectors 30. Thus, each of groups I, II, V and VI is associated with 7 power connectors while each of groups III, IV, VII and VIII is associated with 3 or 4 power connectors. It is noted that typically one power connector in the rack system is designated for backup and another is associated with a

5   main switch, neither of which draws much, if any, current. Thus, the grouping is preferably such that each of groups IV and VIII having 4 power connectors includes one of these low- or no-load power connectors.

[0032]   The provision and configuration of the power distribution terminal block 20 enables the rack system to be easily adapted to different electrical loads and/or different

10   power supply inputs. For example, if each of the power connectors 30 with an actual load (i.e., 40 of the power connectors) draws approximately 0.4A at 208V, then the rack system would draw a total of approximately 16A at 208V. Thus, one 208V/20A, 230V/16A, or 230V/32A power supply circuit or two 115V/16A or 115V/20A power supply circuits would be needed. As is evident, any other suitable combination of power

15   supply circuits may also be used.

[0033]   If the system is upgraded or is operated at greater loads for testing purposes such that each power connector draws approximately 0.7A at 208V, then the rack system would draw a total of approximately 28A at 208V. Thus, one 230V/32A power supply circuit, two 208V/20A or 230V/16A power supply circuits, three 115V/20A power

20   supply circuits, or four 115V/16A power supply circuits would be needed.

[0034]   The computer system can be quickly and easily wired to the corresponding number of circuits using the power distribution terminal block 20. For example, when one circuit is needed, all the groups or terminals, i.e., groups I-VIII, would be connected to the one circuit. Load distribution between two circuits may be easily achieved by

associating each side with one circuit, i.e., terminals for groups I-IV on one circuit and terminals for groups V-VIII on the other circuit. As another example, the load distribution among three circuits may be achieved by connecting each combination of groups I and II, groups V and VI, and groups III, IV, VII and VIII to one of the three circuits. As yet another example, the load distribution among four circuits may be achieved by connecting each combination of groups I and III, groups II and IV, groups V and VII, and groups VI and VIIII to one of the four circuits. The power distribution terminal block 20 may also distribute the power supply among six circuits by connecting each combination of group I, group II, groups III and IV, group V, group VI, and groups VII and VIII to one of the six circuits. As is evident, the power distribution terminal block 20 and its configuration relative to the power connectors 30 allow the input power supply to be provided via 1, 2, 3, 4, or 6 circuits and to be distributed approximately evenly among the corresponding number of combinations of the groups or terminals.

[0035]   It is noted that any other combination of groupings or terminals may be employed. For example, rather than combining groups I and II, groups I and V or groups I and VI may be combined. However, because groups I and II are typically in closer proximity to each other, the combination of groups I and II is preferred. Each combination of groups preferably results in approximately the same number of power connectors (or approximately the same number of power connectors with actual loads).

[0036]   As is evident, the provision and configuration of the power distribution terminal block 20 enables the rack system to be easily configured to work with different electrical loads and/or different power supply inputs. The power distribution terminal block 20 thus enables the rack mount computer systems to be wired and rewired quickly and easily to distribute power from the power supply circuits to the power connectors and

to maintain load balancing among the power supply circuits to prevent circuit overload. The power distribution terminal block 20 also helps to avoid the process of routing and/or rerouting the electrical wiring and/or the power connectors 30 within the rack system even when the power supply input and/or the electrical loads change, e.g., when the rack

5   system is moved to a different location with a different electrical/power input system and/or when the rack system is upgraded or tested. In other words, the configuration of the power distribution terminal block 20 relative to the power connectors 30 generally remains the same while the configuration of the power distribution terminal block 20 relative to the power source can be easily and quickly modified each time the power

10 supply input and/or the electrical load are modified.

[0037]   FIG. 4 is a block diagram illustrating another example of a configuration of a power distribution terminal block 120 to facilitate the configuration of the computer system with varying electrical loads and/or varying power inputs. The configuration shown in **FIG. 4** is similar to that shown in **FIG. 3** except that in **FIG. 4**, two of the

15 groups on each side of the power distribution terminal block 120 are combined into a single group. Specifically, rather than having groups that are 1/6, 1/6, 1/12, and 1/12 of the power connectors 30 on each side of the terminal block, the power distribution terminal block 120 is configured to have groups that are 1/4, 1/6 and 1/12 of the power connectors 30 on each side of the terminal block. As is evident, the configuration of

20 **FIG. 3** provides finer granularity than the configuration of **FIG. 4** such that **FIG. 3** may provide additional grouping combinations that the configuration of **FIG. 4** cannot.

[0038]   The provision and configuration of the power distribution terminal block 120 enables the computer system to be quickly and easily wired to the corresponding number of circuits using the power distribution terminal block 120. For example, with one

circuit, all the groups or terminals, i.e., groups A-F, are simply connected to the one

circuit. Load distribution between two circuits may be easily achieved by associating

each side with one circuit, i.e., terminals for groups A-C on one circuit and terminals for

groups D-F on the other circuit. As another example, the load distribution among three

5   circuits may be achieved by connecting each combination of groups A and C, groups D

and F, and groups B and E to one of the three circuits. As yet another example, the load

distribution among four circuits may be achieved by connecting each combination of

group A, groups B and C, group D, and groups E and F to one of the four circuits. As is

evident, the power distribution terminal block 120 and its configuration relative to the

10   power connectors 30 allow the input power supply to be provided via 1, 2, 3, or 4 circuits

and to be distributed approximately evenly among the corresponding number of

combinations of the groups or terminals. As is evident, the configuration of **FIG. 4**

provides less granularity than the configuration of **FIG. 3** in that the configuration of

FIG. 4 does not provide for approximately even distribution of input power supply from

15   among six circuits.

[0039]   As is evident, variations on the groupings of the power connectors 30 to each

terminal of the power distribution terminal block may be employed. The actual

groupings may depend upon a number of factors, such as the number of the power

connectors 30 (and/or the number of power connectors with actual loads), the load for

20   each power connector 30, and the possible power supply inputs for the computer system.

It is to be understood that although it is common to have the same load for all the power

connectors of the computer system, the computer system may require different loads for

different power connectors and that the power distribution terminal block may be

configured accordingly. However, in typical applications, all servers within a given computer system have the same load, i.e., the same load on each power connector.

[0040]   FIGS. 5-1 and 5-2 are tables illustrating examples of groupings and examples of combinations of groupings for a power distribution terminal block configured similarly to that shown in **FIG. 3** with different number of power connectors adapted to operate with different number of circuits. As shown, the power connectors are divided into four groups of approximately 1/6 and four groups of approximately 1/12 of the total number of power connectors. As is often the case, the total number of power connectors is not evenly divided, i.e., the total number of power connectors is not divisible by 12. Preferably, the groups are divided as closely as possible to 1/6 and 1/12 and so that various combinations of groups can be arranged so that within each set of grouping combinations, the combinations of groups differ by no more than one power connection.

[0041]   Preferably, with N number of power connectors, the grouping of power connectors to each terminal is such that the grouping combinations achieve the maximum practical number of options as to the number of circuits on which the computer system can be configured to operate. Any other suitable division of the power connectors may be similarly implemented.

[0042]   For example, when there are 26 power connectors, the 26 power connectors can be divided in at least one of two ways. As shown in **FIG. 5-1**, the 26 power connectors can be divided into four groups of 4, and two groups each of 3 and 2 power connectors. The groups may then be formed into various sets of combinations for connection to 1, 2, 3, 4 or 6 circuits or outlets such that within each set, the combinations of groups differ by no more than one power connection. For example, in the case of configuring the power connectors to operate on three circuits, each grouping combination

includes either 8 or 9 power connectors satisfying the preferred condition that the combinations of groups differ by no more than one power connection.

[0043]   Similarly, as shown in **FIG. 5-2**, the 26 power connectors can alternatively be divided into two groups each of 5 and 4, and four groups of 2 power connectors. The groups may then be formed into various sets of combinations for connection to 1, 2, 3, 4 or 6 circuits such that within each set, the combinations of groups differ by no more than one power connection. For example, in the case of configuring the power connectors to operate on three circuits, each grouping combination includes either 8 or 9 power connectors satisfying the preferred condition that the combinations of groups differ by no more than one power connection.

[0044]   **FIGS. 6-1** and **6-2** are tables illustrating examples of groupings and examples of combinations of groupings for a power distribution terminal block configured similarly to that shown in **FIG. 4** with different number of power connectors adapted to operate with different number of circuits.

[0045]   **FIG. 7** is a flowchart illustrating a process 150 for configuring the power connectors to the terminals of a power distribution terminal block of a computer system. At step 152, the number of power connectors and the load and/or the total required electrical voltage and amperage for the power connectors are determined. At step 154, the power connectors are grouped into multiple groupings, each corresponding to a terminal of the power distribution terminal block. The grouping may be based at least in part on the likely voltages and ampacities of the possible power sources for the rack system. Each grouping is preferably a portion of the total number of power connectors. It is noted that rather than grouping in terms of a portion of the total number of power connectors, the groupings may be determined in terms of factoring the total number of

power connectors into various groups, taking into account, e.g., a most common factor so as to achieve the maximum practical number of options as to the number of circuits on which the computer system can be configured to operate.

[0046] The groupings are preferably so as to ensure maximum flexibility for combining the groups into a number of combinations equal to the number of circuits needed. Each combination of groups preferably total an approximately equal number of the power connections such that the load on each circuit is approximately equal and the power supplied to each power connection is approximately equal. Preferably, the combinations of groups within any given set of grouping combinations differ by no more than one power connection. At step 156, each group of power connectors are connected to the corresponding terminal in the power distribution terminal block.

[0047] FIG. 8 is a flowchart illustrating a process 200 for configuring a power distribution terminal block of a computer system. At step 202, the total number of circuits or outlets to be connected to the rack system is determined. At step 204, each terminal of the power distribution terminal block is assigned to one of the circuits. Each terminal is connected to a group of the power connectors and each circuit is connected to a combination of the terminals or groups. The combination of the groups is preferably such that the number of power connectors corresponding to each circuit does not differ by more than one. At step 206, the terminals are connected to the corresponding power cable for the corresponding circuit. At step 208, the power cables are connected to the power supply circuits to bring power to the power connectors via the terminals in the power distribution terminal block.

[0048] As is evident, the configuration of the terminals of the power distribution terminal block of a rack mount computer system relative to the power connectors

facilitates the configuration of the rack mount computer system for use with power sources of different voltages and/or ampacities. This is particularly advantageous when the rack mount computer systems are shipped internationally where there is greater variation in the voltage and ampacity of the power supplies. With different voltage and

5   ampacity power supplies at various locations, the rack mount computer systems may need to be configured on-site or configured individually. The power distribution terminal block thus reduces the amount of work and time required to properly configure the rack system for the particular power supply at the destination of the rack system. The power distribution terminal block thus enables the proper and efficient distribution of power and

10   balancing of the load to prevent circuit overload.

[0049]   The power distribution terminal block described herein not only facilitates the configuration of a rack mount computer system to cooperate with different power inputs but can also be utilized to facilitate the configuration of the rack system to cooperate with different internal loads.

15   [0050]   While the preferred embodiments of the present invention are described and illustrated herein, it will be appreciated that they are merely illustrative and that modifications can be made to these embodiments without departing from the spirit and scope of the invention. Thus, the invention is intended to be defined only in terms of the following claims.